One-Way Uplink Ranging for Enhancing Planetary Wind Measurements

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Abstract

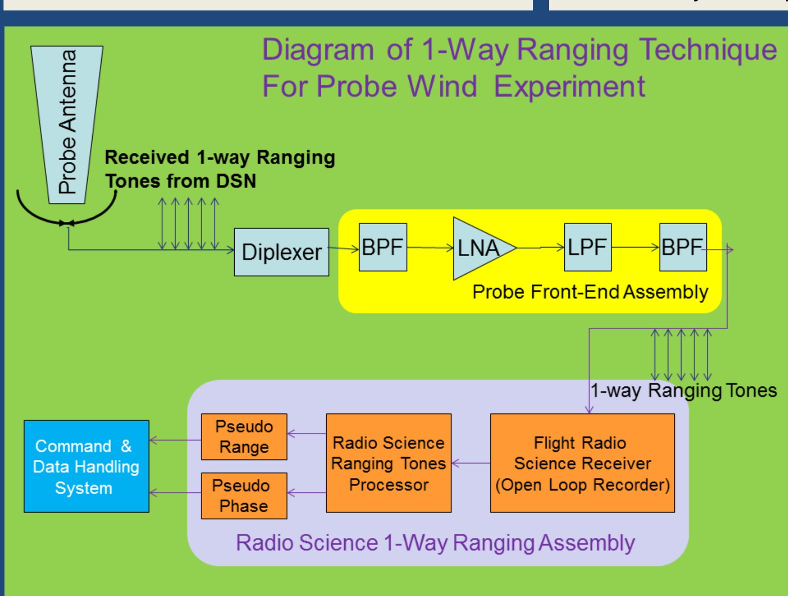
Uplink One-Way Ranging techniques can be used to improve the accuracy of planetary atmospheric wind profiles measured during entry probe descent using Doppler wind techniques. Advances in Radio Science flight instrument technologies and post-processing capabilities allow for the possibility of utilizing a One-Way sequential ranging signal transmitted from Deep Space Network antennas and recorded onboard a probe-mounted Radio Science open-loop receiver with onboard post-processing algorithms to produce precision measurements of probe range and position, thereby significantly improving Doppler retrievals of atmospheric winds.

Benefits of Uplink Ranging

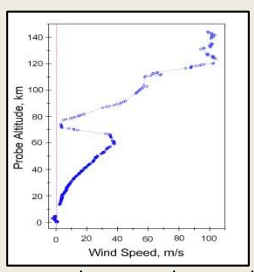
The probe velocity relative to Earth is computed as the derivative of the ranging positional information and is therefore unaffected by any constant biases in the ranging data. In addition, velocities derived from ranging data will not have an error term that grows with the descent time. By providing an accurate Earth-to-probe baseline range and velocity, knowledge of the planet-centered probe descent location can be significantly improved. Additionally, probe measurement of the DSN uplink signal can provide a second projection of the horizontal winds that, when coupled with the probe-orbiter wind projection, will provide the complete horizontal wind vector. To make the measurements fully complementary, the angle between the Earth-to-probe and probe-to-orbiter baselines should be large, and to increase the sensitivity to winds in the probe local horizontal plane, the probe-orbiter and probe-Earth angles should be at a non-zero angle to the probe nadir vector.

Processing Techniques for Ranging

The DSN ranging tone signals immediately after reaching the probe antenna and the probe RF front-end, they get amplified in the Radio Science 1-way Ranging Assembly and down converted into an intermediate frequency. The baseband processor accepts this IF signal, digitizes it, and the stores as I & Q samples in the open loop recorder. These samples are further processed by the Ranging Tone Processor in order to extract the pseudo range and pseudo phase. These two parameters along with information on the received carrier are then transferred into the Probe Command & Data Handling System to be telemetered to the Orbiter.

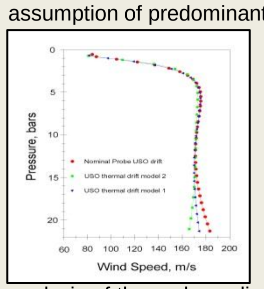


Doppler Wind Measurements of Planetary Winds in the Outer Solar System



The atmospheres of the giant planets represent time capsules dating to the epoch of solar system formation. Atmospheric dynamics - winds, waves, convection, and turbulence - are responsible for horizontal and vertical mixing of atmospheric constituents. The altitude profile of the winds places the location of solar energy deposition structure and the static stability of the atmosphere, and can also provide an indication of the relative importance to the atmospheric energy structure of solar energy relative to internal energy sources.

The dynamics of the atmosphere can be inferred by utilizing Doppler techniques to track the motions of a probe descending under parachute. Accurate modelling of the entry and descent profile of the probe, including location, altitude, and descent speed, and the assumption of predominantly zonal (east-west) winds are used to extract the relatively small signature of probe motions (reflected as Doppler residuals in the probe radio link frequency profile) resulting from atmospheric dynamics. From the Doppler residuals, the vertical profile of zonal winds can be retrieved utilizing an iterative inversion algorithm that accounts for the integrated effect of the winds on the probe descent longitude. Further analysis of the probe radio link frequency residuals may also provide evidence of atmospheric waves and turbulence, as well as probe microdynamics including spin and pendulum motion. The heritage of outer solar system Doppler wind retrievals comprises measurements of the zonal winds on Jupiter by the Galileo probe in 1995 and the Titan zonal decade later. The Jovian zonal wind profile along the path of the Galileo probe descent, retrieved under the assumption of negligible meridional winds and requiring accurate measurement of the probe descent speed, allowed the development of a Doppler residuals inversion algorithm to retrieve the zonal winds while accounting for both the initial uncertainty in probe descent longitude and the changing probe longitude due to the integrated effect of the winds. In 2005 the profile of zonal winds on Titan was measured by the Huygens probe using a significantly simpler retrieval algorithm that did not include probe longitude drift effects in the first iteration, since the small size and slow rotation of Titan make the effect of initial uncertainties and the integrated winds on the probe descent longitude negligibly small.

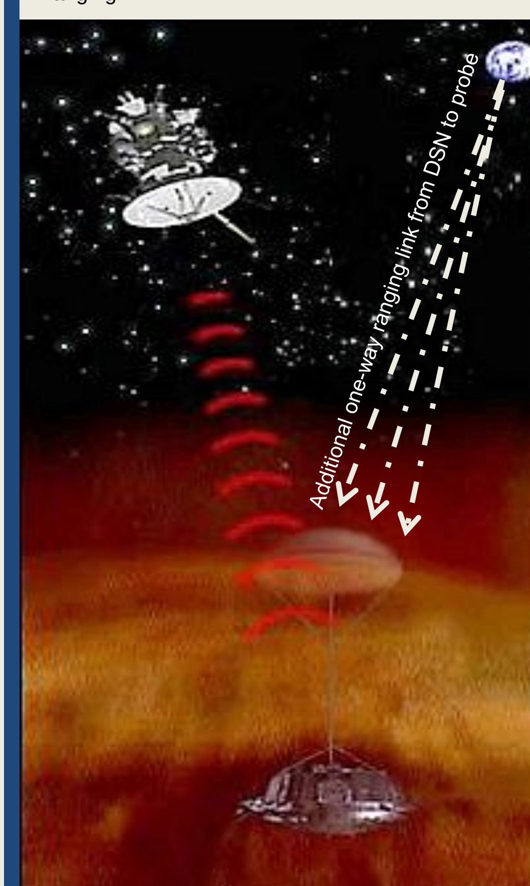


Deep Space Network Ranging Instrument

The Deep Space Network (DSN) will provide the Earth-to-probe connection for this experiment. This uplink from the DSN will be a carrier frequency phase modulated with a Pseudo-Noise (PN) ranging signal. The DSN will use either its 34-meter diameter antennas or 70-meter diameter antennas to produce enough signal margin at the probe's open-loop recorder. The signal margin will be largely determined by the type of probe antenna used to maintain the Earth-pointing link during the wind experiment. Since the probe attitude is expected to vary widely under the turbulent atmospheric conditions, the Earth-pointing link will probably use an omnidirection antenna or low-gain antenna with a large beamwidth. The uplink EIRP capability of the DSN will therefore be a significant factor in the success of this experiment."

Flight Radio Science Receiver

Currently in initial development. Builds on the JPL flight-proven Electra communications payload. Modification for science applications include fixed gain, larger but-depth resulting in higher dynamic range, and better spectral purity and frequency stability. In addition to applications involving better SNR on uplink occultations and one-way uplink ranging.



Acknowledgements

This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.